Amendments to the Specification:

Please replace paragraph [0003] with the following amended paragraph:

[0003] The use of fluorocarbon gas in such processes is advantageous because it can be performed, in situ, that is, in-between chemical deposition procedures being performed on batches of substrates. In situ cleaning procedures, however, are not entirely successful at removing all of the deposits in the chamber. Consequently, after a certain number of hours or days in service, a wipe-clean-out process is required. A wipe-clean-out entails opening up the chamber and mechanically cleaning deposits off ~~of~~ all surfaces inside the chamber. It is desired within the industry to keep the number of wipe-clean-outs to a minimum during the manufacturing process because this necessitates taking the tool out of the fabrication process for several hours, which diminishes both production ~~time, and~~ <u>time and,</u> therefore, product output.

Please replace paragraph [0005] with the following amended paragraph:

[0005] In some instances, for example, an in situ cleaning process is performed after every deposition procedure. Such procedures, however, are practical only for certain types of PECVD tools having a small deposition chamber, for example, a chamber that can accommodate one wafer, and typically used for depositing thin material layers (e.g., less than about 400 Angstroms). In situ cleaning after every deposition is inefficient for tools having larger chambers that accommodate several wafers and <u>are</u> typically used for depositing thick material layers (e.g., greater than about 600 Angstroms), because the cleaning cycle time between batches of wafer would be unacceptably long. Moreover, frequent cleaning of the larger chamber would entail increased use of fluorocarbon cleaning gas and increased perfluorocarbon emissions.

Please replace paragraph [0011] with the following amended paragraph:

[0011] The invention is best understood from the following detailed description when read with the accompanying ~~FIGUREs~~ drawings. It is emphasized that in accordance with the standard practice in the semiconductor industry, various features may not be drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion. Reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

Please replace paragraph [0012] with the following amended paragraph:

[0012] FIGURE 1 ~~illustrate~~ illustrates by flow diagram, selected steps of one embodiment of a cleaning process of the present invention;

Please replace paragraph [0014] with the following amended paragraph:

[0014] FIGURESs~~s~~ 3A to 3C illustrate cross-sectional views of selected steps of an embodiment of a method of manufacturing a semiconductor device according to the principles of the present invention.

Please replace paragraph [0015] with the following amended paragraph:

[0015] The present invention recognizes the advantageous use of a three-step cleaning process using perfluorocarbon gases (CxFy) for cleaning a deposition chamber with multiple substrate stations contained therein. When implementing a cleaning process using perfluorocarbon gases that have higher reactivity than hexafluoroethane (C_2F_6), conventional two-step cleaning processes are unacceptable. The cleaning process using these perfluorocarbon gases is further complicated by software limitations that run certain commercial deposition tools. Further, extensive amounts of time are spent calibrating the deposition tool to a particular manufacturing process. Once the tool is purchased and calibrated, manufacturers are extremely reluctant to change the deposition tool because it could mean a complete ~~re-calibration~~ recalibration of the tool, which could mean

additional process uncertainty. This, of course, is highly undesirable in an industry where production ~~through put~~ throughput and product quality are paramount. It was found that the software limitations presented a considerable obstacle in getting a deposition chamber cleaned to the extent necessary to maintain desirable intervals between wipe-clean-out procedures. As further illustrated in the example section below, two-step cleaning processes do not adequately remove deposits in chambers having multiple substrate stations, particularly deposits on the showerheads at each station. Consequently, there is poor control of the uniformity of thickness of oxide layers being deposited on substrates. This, in turn, necessitates more frequent wipe-clean-out procedures on the deposition chamber than desired.

Please replace paragraph [0016] with the following amended paragraph:

[0016] The present invention benefits from the realization that introducing a third step into the cleaning process dramatically improves the removal of deposits ~~on~~ from the showerheads. Improvements in cleaning obtained by the addition of a third cleaning step facilitates ~~the~~ using low quantities of certain perfluorocarbon gases, thereby reducing the costs and perfluorocarbon emissions. Moreover, the time between wipe-clean-out procedures is maintained at acceptable periods.

Please replace paragraph [0020] with the following amended paragraph:

[0020] The chemical composition of deposits that form on the interior surfaces of the chamber during the manufacturing process 135 ~~depend~~ depends on the type of deposition procedure being performed and the composition of the chamber. For instance, when silicon oxide, silicon oxynitride, ~~or and~~ or/and silicon nitride layers are formed on a substrate, deposits in aluminum chambers are composed primarily of aluminum and silicon oxides and aluminum and silicon nitrides, respectively. As further discussed below, in certain preferred embodiments, the cleaning process 100 is initiated in step 160, if the deposits in the chamber exceed a predefined limit. In some embodiments the

cleaning process is commenced, for example, when the thickness of deposits inside the chamber reaches a predefined maximum, such as about 8 micron thick.

Please replace paragraph [0021] with the following amended paragraph:

[0021] One skilled in the art would understand that the fluorocarbon gases serve as etchants that react with the deposits to produce cleaning by-products. Such byproducts can be removed from the chamber in step 170 through gas outlets in the chamber. In certain preferred embodiments of the process 100, it is desirable to use fluorocarbon gases having a higher reactivity or a higher fluorine content (i.e., CxFy with y > 6) than hexafluoroethane. Such characteristics advantageously allow the use of reduced quantities of cleaning gas. In some preferred embodiment, for example, the fluorocarbon gas is selected from the group consisting of: ~~C_3F_8; C_4F_8; and C_4F_8O~~ octafluoropropane (C_3F_8), cyclic-octafluorobutane (c-C_4F_8), and octafluorotetrahydrofuran (C_4F_8O).

Please replace paragraph [0022] with the following amended paragraph:

[0022] One skilled in the art would understand that cessation of the first cleaning step 110 may be prompted by any number of endpoints, in step 180. In some embodiments of the process 100, for instance, the endpoint 180 corresponds to a change in the concentration of cleaning by-products, such as an increase in fluorine and decrease carbon monoxide, produced from reactions between the fluorocarbon gas and oxide deposits in the chamber. In certain preferred embodiments, the optical emissions from the by-products in the chamber are monitored during the cleaning process. Changes in the concentrations of fluorine and carbon monoxide can be followed by measuring their optical emission signals at 704 and 483 nanometers, respectively, for example. In some embodiments, therefore, the duration of the first cleaning step 110 depends upon the amount of deposits inside the chamber. For example, in certain embodiments, when there is an 8 micron thick layer of oxide deposits inside the ~~chamberat~~ chamber at the

start of the process 100, the endpoint 180 for the first cleaning step 110 is reached after a period of about 15 to about 20 minutes.

Please replace paragraph [0023] with the following amended paragraph:

[0023] In some embodiments of the process 100, a second cleaning step 120 of short duration is desirable because this reduces the total time spent on cleaning, thereby maintaining the productive throughout of the tool. In particular, it is advantageous to adjust the duration of the second cleaning step so as not to extend beyond the time necessary to ensure adequate cleaning of ~~shower heads~~ showerheads in the deposition chamber. In certain preferred embodiments, therefore, the duration of the second cleaning step 120 is for a fixed time and is substantially less (e.g., less than about 25 percent) than the duration of the first cleaning step 110. In some preferred embodiments, for example, the second cleaning step lasts for a period ranging from about 10 to about 240 seconds, and more preferably about 30 seconds.

Please replace paragraph [0024] with the following amended paragraph:

[0024] In still other embodiments of the process 100, it is preferable for the duration of the third cleaning step 130 to be a function of the duration of the first cleaning step 110. In some preferred embodiments, for instance, the third cleaning step 130 lasts for a period equal to fixed time plus a fraction of the duration of the first cleaning step 110. The particular values chosen for the fixed time and fraction depend upon the extent of over-cleaning that is desired. Consider an embodiment of the process where the endpoint 180 is monitored by measured cleaning by-product produced at one location in the chamber. In certain embodiments, it is desirable to extend the duration of the third cleaning step 130 in order to ensure complete cleaning the other locations that are more difficult to clean than the monitored location. As an example, consider an embodiment where the endpoint of the first cleaning step is reached in 15 minutes. In such an embodiment, the

duration of the third cleaning step 130 can equal about 375 seconds, that is, 150 seconds plus 25 percent of the duration of the first step 110[[,]] (i.e., 225 seconds).

Please replace paragraph [0026] with the following amended paragraph:

[0026] The flow rate of the fluorocarbon gas ~~passes~~ passed into the deposition chamber during the cleaning steps 110, 120, 130 strikes a balance between efficient cleaning and reducing the amount of fluorocarbon gas used. In certain preferred embodiments of the process 100, the first cleaning step 110 includes passing the fluorocarbon gas into the deposition chamber at a first flow rate between about 600 and about 1200 sccm (std. cm^3/min), and more preferably about 850 sccm. In other preferred embodiments, the second cleaning step 120 includes passing the fluorocarbon gas into the deposition chamber at a second flow rate substantially equal to the first flow rate. In still other preferred embodiments, the third cleaning step 130 includes passing the fluorocarbon gas into the deposition chamber at a third flow rate that is less, and more preferably substantially less (e.g., about 60 percent ~~less~~), than the first and second flow rates. In some preferred embodiments, for example, the third flow rate is between about 300 and about 1200 sccm, and more preferably about 500 sccm.

Please replace paragraph [0027] with the following amended paragraph:

[0027] Certain preferred embodiments of the cleaning process 100 further include passing oxygen gas (O2) into the deposition chamber during the cleaning steps 110, 120, 130. A cleaning gas that comprises a mixture of oxygen and fluorocarbon gas has increased reactivity as compared to a fluorocarbon alone, and therefore the total duration needed for cleaning is reduced. In some embodiments, the reactivity of the cleaning gas mixture is increased by using an oxygen-rich cleaning gas mixture. For instance, the ratio of the flow rate of oxygen to the flow rate of fluorocarbon gas is maintained between about 2:1 and about 4:1 during the cleaning steps 110, 120, 130. In embodiments using the above-cited flow rates of fluorocarbons, for example, the flow

rate of oxygen gas into the deposition chamber is between about 1900 and about 3000 sccm during the first and second cleaning steps 110, 120, and between about ~~100~~ 1000 and about 2000 sccm during the third cleaning step 130.

Please replace paragraph [0032] with the following amended paragraph:

[0032] Yet another embodiment of the present invention is illustrated in the block diagram of FIGURE 2, in the form of a system 200 for cleaning a deposition chamber 205. In some embodiments, the system 200 includes a deposition chamber 205 having multiple substrate stations 210 contained therein. In certain preferred embodiments, each substrate station 210 has a showerhead 215 with proximal (face 216a) and distal (edge 216b) sides . The system 200 further includes a detector 220 configured to monitor cleaning by-products of deposits 225 in the deposition chamber 205. The system 200 also includes a controller 230 configured to provide at least three cleaning steps and to initiate a transition from one to another of the cleaning steps in response to a signal 235 from the detector 220. Any of the above-described embodiments of the three-step cleaning process of the present invention, illustrated in FIGURE 1 and discussed above, can be used in the system 200.

Please replace paragraph [0034] with the following amended paragraph:

[0034] In particular embodiments of the system 200, where the controller 230 was originally configured to conduct a two-step cleaning process, the controller 230 is modified to provide a three-step cleaning process controller 230. Such embodiments of the system 200 further include using the three-step cleaning process controller 230 to conduct the first, second and third cleaning steps described above and illustrated in FIGURE 1. In yet other embodiments, the controller 230 further includes one or more valves 245 for introducing fluorocarbon and other gases into ~~said~~ the deposition chamber 205. For example, in some preferred embodiments, the controller 230 is configured to actuate the flow of cleaning gases, such as ~~octofloropentane~~ octafluoropropane (C_3F_8)

and oxygen through showerheads 215 inside the deposition chamber 205. In other preferred embodiments, the controller 230 is also configured to regulate a radio frequency power source 250 used to generate a plasma inside the deposition chamber 205 during the cleaning process.

Please replace paragraph [0035] with the following amended paragraph:

[0035] Still other embodiments of the system 200 further include a computer 255 configured to read a data file 260 having settings for the at least three cleaning steps used by the controller 230. Such ~~setting~~ settings can include parameters such as gas flow rates, radio frequency power settings, chamber pressures and the durations of particular settings. Other embodiments of the system 200 also include a computer readable media 265 capable of causing the computer 255 to produce a control signal 270 that causes the controller 230 to initiate the three-step cleaning process, transition from one cleaning step to the next, or to cease the cleaning cycle. The computer readable media 265 can comprise any computer data storage tools including, but not limited to, hard disks, CDs, floppy disks, and memory or firmware.

Please replace paragraph [0036] with the following amended paragraph:

[0036] Yet another embodiment of the present invention is a method of manufacturing semiconductor devices. ~~FIGUREs~~ FIGURES 3A to 3C illustrate ~~cross sectional~~ cross-sectional views of selected steps of an embodiment of a method of manufacturing a semiconductor device 300 according to the principles of the present invention. Turning first to FIGURE 3A, the method includes transferring a plurality of substrates 305 into a deposition chamber 310 having multiple substrate stations 315 contained therein. Preferably the deposition chamber includes a plurality of shower heads 320, respectively located at each of the substrate stations 315.

Please replace paragraph [0037] with the following amended paragraph:

[0037] As shown in FIGURE 3B, material layers 325 are deposited on the substrates 305. In certain embodiments of the method 300, the material layers 325 are inter-level, or in other embodiments, [[a]] top level, dielectric layers 325. In certain processes, for instance, the material layers 325 may be silicon dioxide, silicon nitride or silicon oxynitride. In certain preferred embodiments the deposition is carried out using conventional CVD or PECVD procedures, well known to those skilled in the art.

Please replace paragraph [0041] with the following amended paragraph:

[0041] The following examples are presented to illustrate the effectiveness of the three-step cleaning process of the present invention as compared to a conventional two-step cleaning process. A two-chambered PECVD tool (Novellus Sequel System, Novellus Systems, Inc., San Jose, CA) having six stations per chamber was used. For test purposes, an about 12,000 Angstrom thick ~~layers~~ <u>layer</u> of silicon dioxide was deposited on silicon wafers using a conventional TEOS process. The tool was configured to run an intermittent in situ cleaning process when the total thickness of oxide deposited on the surfaces inside the chamber was greater than about 8 microns. The thickness of the oxide deposit was estimated based on the deposition rate parameters used in the TEOS process.

Please replace paragraph [0042] with the following amended paragraph:

[0042] The tool was also configured to run the TEOS PECVD process for a maximum period of fifty hours of TEOS deposition, after which a wipe-clean-out process was performed on the deposition chamber. The need for a wipe-clean-out process ~~early~~ <u>earlier</u> than this ~~is~~ <u>was</u> indicated, however, if the variation in the thickness of silicon dioxide layers being deposited on silicon wafers varied by more than a predefined limit across batches of 24 wafers. Typically, the thickness of the first and last wafer in each batch was monitored using conventional reflectometry or ellipsometry procedures. When the variability in thickness exceeded the predefined limit of about 5 percent a wipe-clean-out is performed.

Please replace paragraph [0046] with the following amended paragraph:

[0046] Exemplary results obtained from three trial runs using the two-step cleaning process are presented in TABLE 2. When running the two-step cleaning process, summarized in TABLE 1, thickness variations across batches of wafer indicat~~ing~~ed that a wipe-clean-out procedure was needed between about 15 and about 18 hours before the 50 hour maximum period for running the TEOS PECVD process. The deposition chamber was inspected before doing the wipe-clean-out procedure. Two-step processes did not adequately remove deposition particles in the chamber, particularly deposits on the sides of the showerheads. The build-up of such deposits result~~s~~ed in unacceptable thickness variations of oxide layers being deposited on wafer substrates. In certain instances, the deposits flaked off the ~~shower head~~ showerhead and landed on the surface of wafer substrates. In other instances, as deposits ~~build~~ built up on the sides of the showerheads, the deposition rate of oxide layers was reduced. Moreover, simply increasing the pressure inside the chamber or flow rate of fluorocarbon and oxygen gas during the first step did not reduce the build-up of deposits on the sides of the showerheads.

Please replace paragraph [0048] with the following amended paragraph:

[0048] To circumvent these problems, a third-cleaning step was introduced. It was hypothesized that a third step having a high chamber pressure or high flow rate of fluorocarbon gas would prevent the build-up of deposits ~~of the~~ on both the proximal and distal sides of the showerheads. To implement a three-step cleaning process on the Novellus Sequel System, it was necessary to reconfigure the software program that controls the two-step cleaning process originally provided with the system, into a three-step process. In particular, new parameters to control O2 flow, chamber pressure, RF power, fluorocarbon gas flow rate and duration of the third step were created. An example of a portion of a reconfigured program containing the added third step, designated as “Mid,” is presented in TABLE 3.

Please replace paragraph [0050] with the following amended paragraph:

[0050] The results obtained for three trials using a three-step cleaning ~~process, is~~ process are presented in TABLE 4. Surprisingly, when running a three-step cleaning process, such as that summarized in TABLE 1, thickness variations in an oxide layer deposited on different batches of wafers did not exceed the predefined limit, and therefore an early wipe-clean-out procedure was not required. Moreover, inspection of the chamber prior to a wipe-clean-out revealed that there was no build-up to deposits on the sides of the ~~shower heads~~ showerheads, unlike that observed when using the two-step cleaning process.